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(54) **METHOD FOR ENHANCING SCINTILLATOR ADHESION TO DIGITAL X-RAY DETECTORS**

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(52) **U.S. Cl.** **250/370.11**; 250/363.2; 250/367; 250/370.09

(58) **Field of Search** 250/370.11, 363.2, 250/367, 370.09

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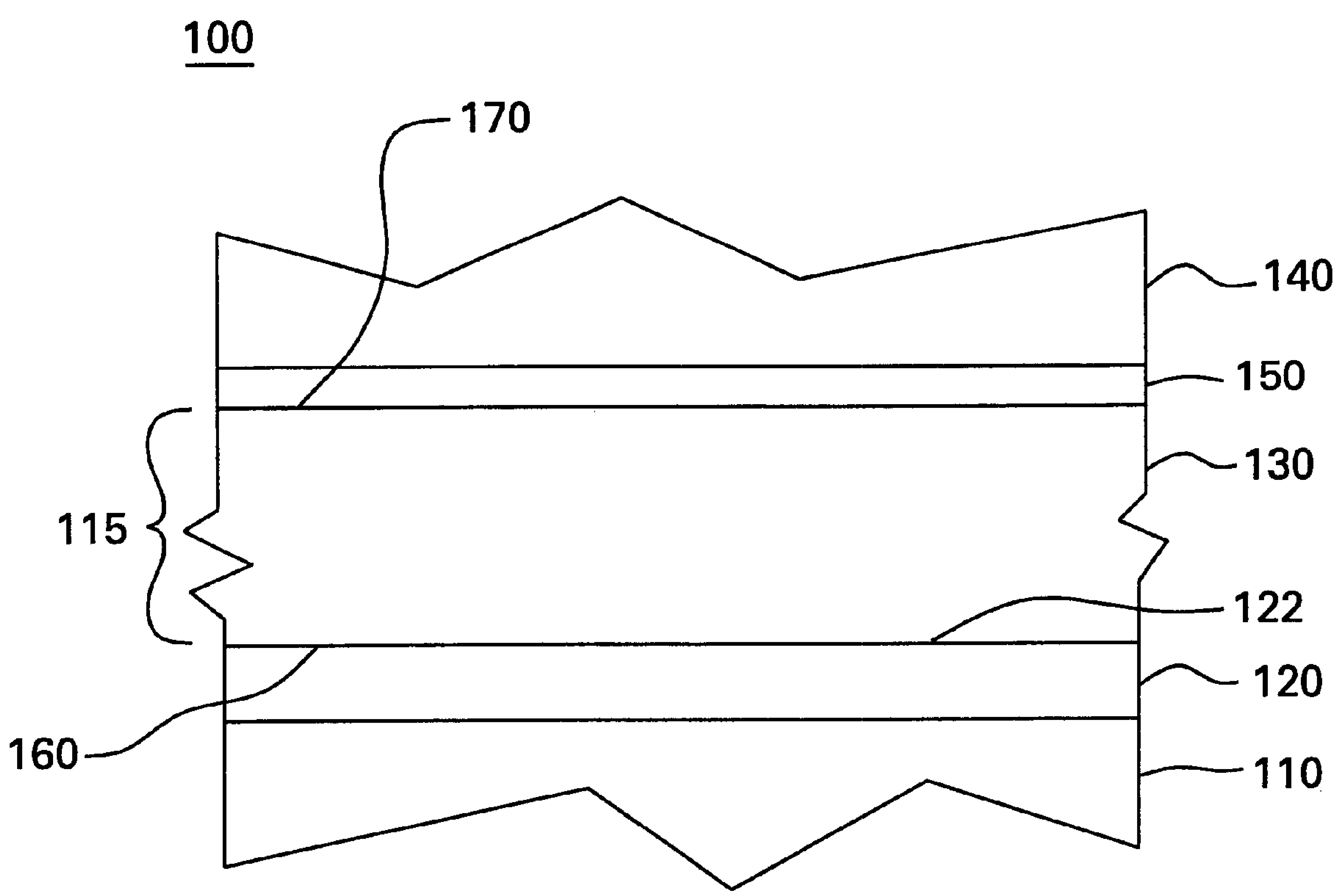
(57) **ABSTRACT**

The present invention provides a process and apparatus for forming a high integrity imager device having a passivation layer disposed over a photosensor array, a passivation layer with an adhesion topography on its surface, and a scintillator layer disposed over the passivation layer such that the scintillator layer is coupled to the adhesion topography.

39 Claims, 3 Drawing Sheets



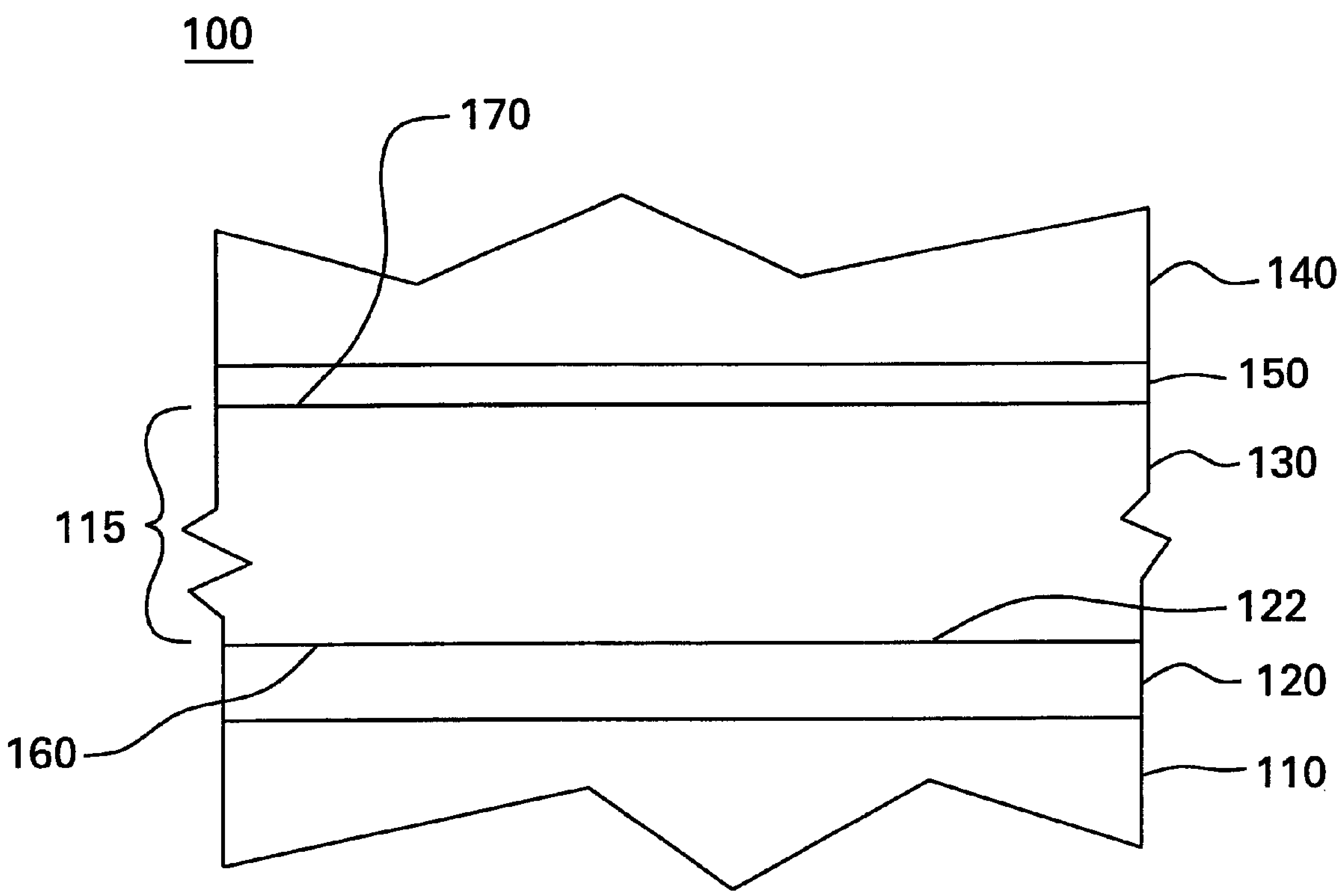


FIG.1

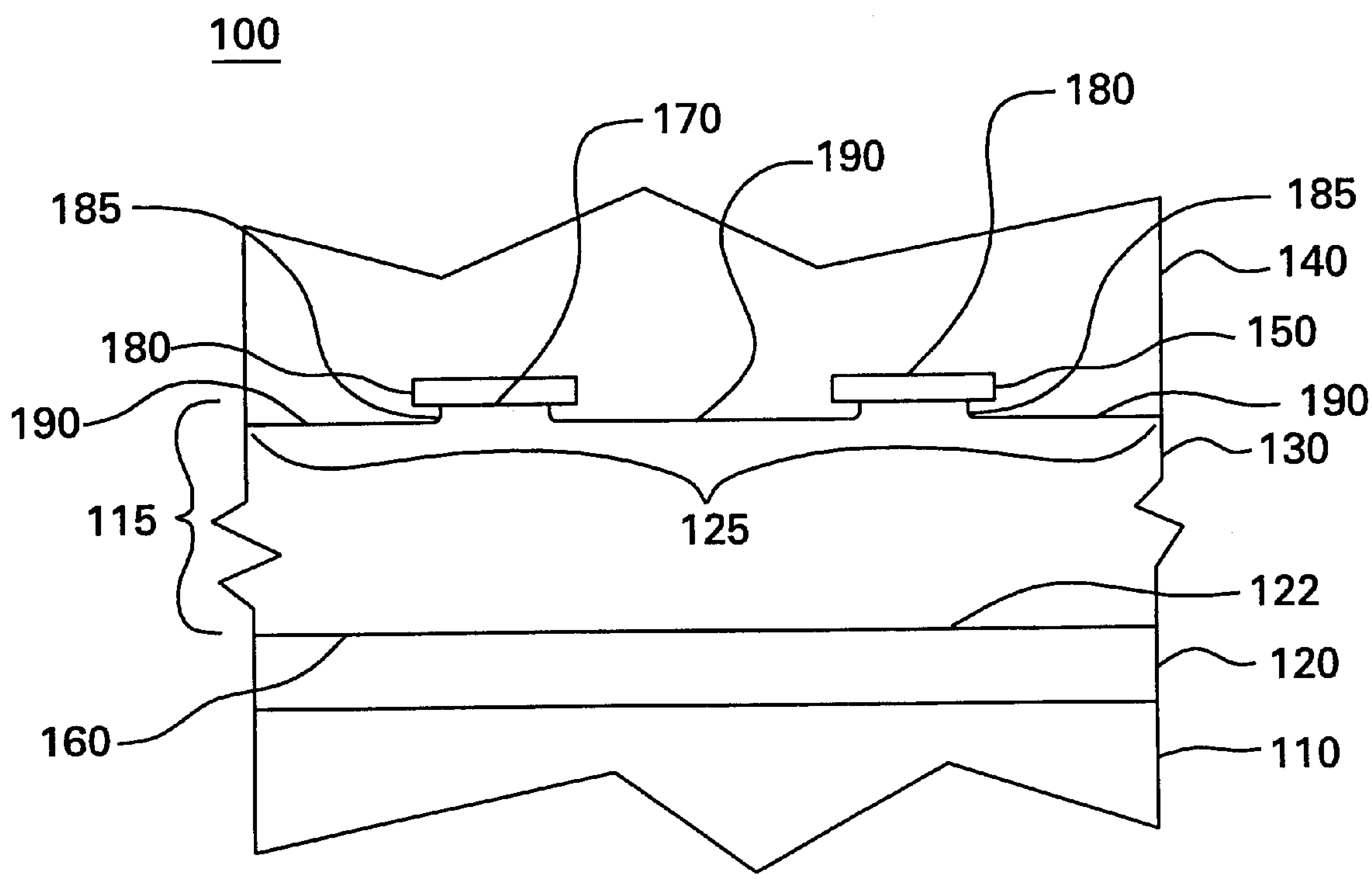

100
170
180
190
185
185
140
180
150
190
190
130
115
125
122
120
160
110

FIG.2

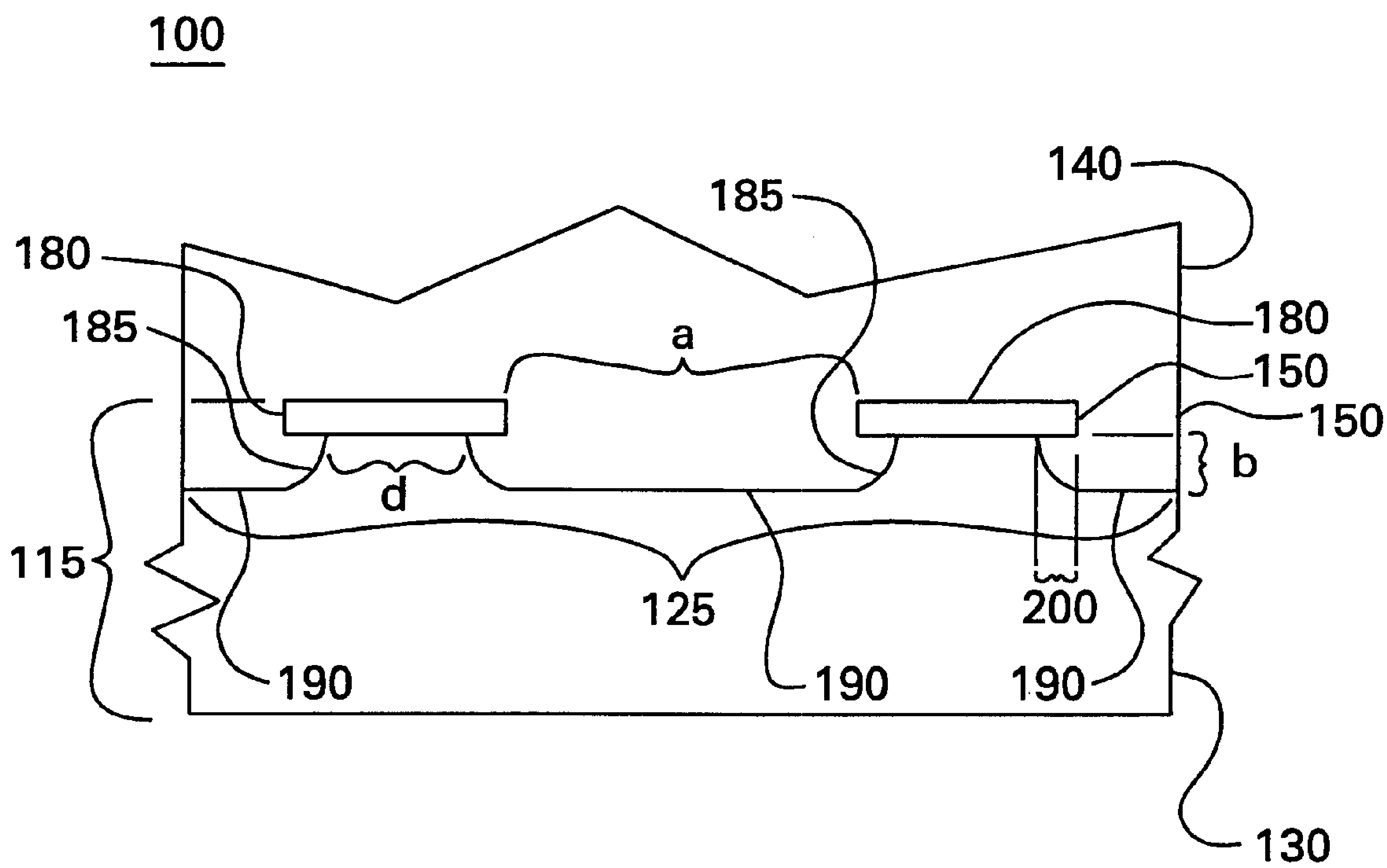


FIG.3

METHOD FOR ENHANCING SCINTILLATOR ADHESION TO DIGITAL X-RAY DETECTORS

BACKGROUND OF THE INVENTION

This invention relates generally to digital imaging, and more particularly to x-ray detector imaging.

Radiation imagers, such as digital x-ray imagers, typically include a scintillator coupled to a photosensor array. The radiation to be detected, x-rays for example, are absorbed by the scintillator material with the release of electrons which are converted to optical photons inside the scintillator that in-turn are detected by photodiodes which accumulate charge corresponding with the incident photons. The charge is read out by drive electronics to provide electrical signals corresponding to the radiation image. The data embodied in such electrical signals can be presented in a visual display or otherwise processed to allow analysis of the radiation pattern.

Optimal array performance depends on, among other things, good adhesion between the scintillator layer and the underlying photosensor array. When CsI is evaporated on the surface of a passivation layer, for example, thermal expansion results in forces that tend to peel the CsI layer from the surface of the passivation layer over the photosensor array. As a result, attempts have been made to increase the adhesion of evaporated CsI to a photosensor array; approaches include etching the surface of the underlying passivation layer, typically comprising of Si_3N_4 (generally referred to as SiN), or adding a buffer layer of polyimide over the photosensor array. While these attempts have been successful within certain temperature ranges, adhesion problems begin to develop at extreme temperature ranges beyond −20 degrees Celsius to +70 degrees Celsius.

There are a number of factors that affect the reliability of the adhesion between CsI and the substrate. For example, a large stress on the CsI-substrate interface may result because of the difference in coefficient of thermal expansion between CsI (typically having a large thickness of 100 to 600 microns(μm)) and the imager glass substrate. Attempts to structure the surface under the CsI layer have consisted, for example, of depositing a thick (~5 μm) polyimide layer over the photodiode to form a platform on which the CsI is deposited; nevertheless, such attempts have not always provided the desired level of adhesion.

Accordingly, there is a need in the art for a radiation imager having good adhesion between the scintillator and photodiode array.

SUMMARY OF THE INVENTION

The present invention provides a process and apparatus for forming a high integrity imager device having a passivation layer disposed over a photosensor array, a passivation layer with an adhesion topography on its surface, and a scintillator layer disposed over the passivation layer such that the scintillator layer is coupled to the adhesion topography.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic, cross-sectional view of one embodiment of the instant invention.

FIG. **2** is a schematic, cross-sectional view of another embodiment of the instant invention.

FIG. **3** is a schematic, cross-sectional view of another embodiment of the instant invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a schematic, cross-sectional view of a portion of a radiation imager **100**. Radiation imager **100** typically comprises a photosensor array **120** disposed on a substrate **110**. A scintillator **140** is optically coupled to photosensor array **120**. "Optically coupled" as used herein, refers to the disposition of scintillator **140** and photosensor array **120** so that optical photons from scintillator **140** readily pass from scintillator **140** into photosensor array **120**. A protective cover plate (not shown) is disposed over scintillator **140** so as to protect scintillator **140** from exposure to ambient conditions.

FIG. **1** depicts a passivation layer **115**, typically comprising one or more passivation tiers (e.g. a first tier **130** and a second tier **150**), that is disposed on photosensor array **120**. As used herein, "on", "over", "above", "under" and the like are used to refer to the relative location of elements of imager **100** as illustrated in the figures and is not meant to be a limitation in any manner with respect to the orientation or operation of imager **100**. One characteristic of passivation layer **115** is that it be optically transmissive so that light generated in the scintillator layer reaches photosensor array **120**. "Optically transmissive" as used herein, is the characteristic of the passivation layer **115** to allow light to reach photosensor array **120** through passivation layer **115**. Passivation layer **115** typically has an optical transmission (that is, passes right through passivation layer **115**) in the range between about 60% and about 100%. Such optically transmissive layers, for example, may comprise but are not limited to, SiN and SiO_2. These passivation materials also prevent moisture, for example, from reaching photosensor array **120** and aid in maintaining adhesion to the underlying structures.

In one embodiment, passivation layer **115** typically comprises a first tier **130** and a second tier **150**. For example, passivation layer first tier **130** typically comprises SiN and passivation layer second tier **150** comprises SiO_2. The SiN tier is typically non-stoichiometric ($Si_{3X}N_{4(1-X)}$ with X only approximately equal to 1) but it may also be stoichiometric Si_3N_4 (hereinafter referred to as SiN). The SiN tier has a thickness in the range between about 0.1 μm and about 5 μm. The SiO_2 tier has a thickness in the range between about 0.1 μm and about 2 μm. Passivation layer first tier first surface **160** is disposed over photosensor array first surface **122** and passivation layer second tier **150** is disposed in contact with passivation layer first tier second surface **170**.

FIG. **2** depicts an adhesion topography **125** comprising a plurality mesa tops **180** and a plurality of depressions **190** formed within passivation layer **115**. Adhesion topography **125** is created when etchants are used to etch mesa tops **180** and depressions **190** on passivation layer **115**. Evaporated scintillator material **140** is attached to passivation layer **115** adhesion topography **125** by scintillator material **140** being disposed within depressions **190** formed by the etched out area. Mesa tops **180** are disposed between respective depressions **190** and are either flush with or extend beyond the underlying sidewalls **185** of depressions **190**. The shape (in plan view) of mesa tops **180**, for example, includes square, circular, rectangular, or irregular shapes.

Adhesion topography **125** is typically formed by first using photolithography steps to etch mesa tops **180** in passivation layer **115** (FIG. **3**). For example, one method of etching includes etching passivation layer second tier **150** using an etchant that does not etch passivation layer first tier **130**, leaving portions of passivation layer second tier **150** that will constitute mesa top **180** structure. The distance "a" between the respective edges of adjacent mesa tops **180** is typically in the range between about 2 μm and about 500 μm. Next, passivation layer first tier **130** is partially etched to a depth "b" of about 0.1 μm, using an etchant that does not etch passivation layer second tier **150**, leaving a depression **190** in passivation layer first tier **130**. As a result, an undercut **200** is created extending under mesa top **180** surface. Typical etchants used for etching passivation layer **115** comprise hydrofluoric acid or plasma etching. The edge of undercut **200** is either flush with or is recessed beyond the edge of mesa top **180**. The length of mesa top **180** undercut **200** is typically in the range between about 0 μm and about 1 μm. The distance "d" between adjacent depressions **190** is typically in the range between about 5 μm and about 500 μm.

Alternatively, another method of etching involves using at least one etchant that etches passsivation layer first tier **130** material much faster than passivation layer second tier **150** material. Thus, once passivation layer second tier **150** material is etched through, passivation layer first tier **130** material etches quickly creating an undercut **200** under mesa top **180** left by passivation layer second tier **150** material etching. For SiN and SiO_2 materials, for example, a liquid dilute hydrofluoric acid can etch SiN much faster than SiO_2; the relative etch rates of the two materials depend on the stoichiometry of the SiN (since SiN may be $Si_{3X}N_{4(1-X)}$).

In another embodiment of this invention, passivation layer first tier **130** comprises either SiN or SiO_2 and passivation layer second tier **150** comprises a polyimide layer. Polyimides are polymer materials that are widely used in semiconductor devices that are heated without decomposing. For example, a 0.5 μm thick polyimide layer is spin coated on top of passivation layer first tier **130**. Polyimide layer (passivation layer second tier **150**) is etched by a plasma etch process, for example, to achieve mesa top **180** pattern desired. Next, passivation layer first tier **130** is etched with a dilute hydrofluoric acid, for example, that does not etch the polyimide layer leaving undercut **200** under mesa top **180** structure.

As a result, adhesion topography **125** of the high integrity imager device **100** passivation layer **115** surface is defined by a series of depressions **190** and a series of mesa tops **180**, disposed between depressions **190**, which in conjunction allow the deposition of scintillator material **140** into depression **190**. "High integrity," as used herein, is defined as the disposition of the scintillator material **140** over the surface of mesa tops **180** as well as into depressions **190** provides a high integrity bond between scintillator **140** and the underlying passivation layer **115**. As a result, there is little or no mechanical deterioration, peeling or motion of the bond between scintillator **140** and adhesion topography **125** at extreme temperature ranges typically between about −20 degree Celsius and about 70 degrees Celsius. For example, the structure should pass the standard tape pull test (wherein the adhesive tape is applied to the structure and pulled off, as is known in the art) without peeling or delamination.

It will be apparent to those skilled in the art that, while the invention has been illustrated and described herein in accordance with the patent statutes, modification and changes may be made in the disclosed embodiments without departing from the true spirit and scope of the invention. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

What is claimed is:

1. A process for forming a high integrity imager device, comprising the steps of:

forming an adhesion topography in a passivation layer surface, said adhesion topography comprising an upper surface of said passivation layer; and

depositing a scintillation layer on said passivation layer surface.

2. A process for forming a high integrity, imager device in accordance with claim **1**, wherein said adhesion topography comprises depressions formed within said passivation layer and a plurality of mesa tops disposed between said depressions.

3. A process for forming a high integrity imager device in accordance with claim **1**, wherein the distance between adjacent ones of said mesa tops is in the range between about 2 μm and about 500 μm.

4. A process for forming a high integrity imager device in accordance with claim **2**, wherein the distance between adjacent ones of said depressions is in the range between about 2 μm and about 5 μm.

5. A process for forming a high integrity imager device in accordance with claim **1**, wherein said scintillation layer comprises Cesium Iodide.

6. A process for forming a high integrity imager device in accordance with claim **2**, wherein said scintillation layer is disposed within said depressions and over said mesa tops.

7. A process for forming a high integrity imager device in accordance with claim **1**, wherein the steps of forming said adhesion topography comprises the steps of:

forming a 1^{st} passivation tier, said 1^{st} passivation tier having a respective 1^{st} and 2^{nd} surface;

depositing a 2^{nd} passivation tier, having a respective 1^{st} and 2^{nd} surface, on said 1^{st} passivation tier, said 2^{nd} passivation tier 1^{st} surface is in contact with said 1^{st} passivation tier 2^{nd} surface;

etching said 2^{nd} passivation tier to form a plurality of mesa tops therein, said mesa tops having a depth from said 2^{nd} passivation tier 2^{nd} surface to said 2^{nd} passivation tier 1^{st} surface; and

etching said 1^{st} passivation tier second surface to form a plurality of depressions in the region between said mesa tops.

8. A process for forming a high integrity imager device in accordance with claim **7**, wherein the step of forming said depressions includes etching said first passivation layer such that sidewalls of said depressions are flush with said overlying mesa tops or extend beneath said mesa tops creating an undercut portion.

9. A process for forming a high integrity imager device in accordance with claim **8**, wherein said undercut has a length in the range between about 0 μm and about 1 μm.

10. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 1^{st} passivation tier and said 2^{nd} passivation tier respectively comprise of two different passivation materials.

11. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 2^{nd} passivation tier comprises a polyimide layer.

12. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 2^{nd} passivation tier comprises a SiO_2 layer.

13. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 2^{nd} passivation tier has a thickness in the range between about 0.1 μm and about 5 μm.

14. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 1^{st} passivation tier comprises a SiN layer.

15. A process for forming a high integrity imager device in accordance with claim **7**, wherein said 1^{st} passivation tier has a thickness in the range between about 0.1 μm and about 2 μm.

16. A process for forming a high integrity imager device in accordance with claim **7**, wherein a process for forming adhesion topography comprises the steps of:

etching said 2^{nd} passivation tier using a 1^{st} etchant which etches said 2^{nd} passivation tier but does not etch said 1^{st} passivation tier; and

etching said 1^{st} passivation tier using a 2^{nd} etchant which etches said 1^{st} passivation tier but does not etch said 2^{nd} passivation tier.

17. A process for forming a high integrity imager device in accordance with claim **16**, wherein etching said 1^{st} passivation tier using said 2^{nd} etchant which etches said 1^{st} passivation tier but does not etch said 2^{nd} passivation tier comprises plasma etching.

18. A process for forming a high integrity imager device in accordance with claim **17**, wherein said 2^{nd} etchant comprises hydrofluoric acid.

19. A process for forming a high integrity imager device in accordance with claim **7**, wherein a single etchant can be used to etch said 1^{st} and 2^{nd} passivation tiers.

20. A process for forming a high integrity imager device in accordance with claim **19**, said single etchant comprises hydrofluoric acid.

21. A radiation imager comprising:

a passivation layer having an adhesion topography, said adhesion topography comprising an upper surface of said passivation layer; and

a scintillation layer disposed over said adhesion topography.

22. A radiation imager in accordance with claim **21**, wherein said passivation layer adhesion topography comprises depressions formed within said passivation layer and a plurality of mesa tops disposed between said depressions.

23. A radiation imager in accordance with claim **21**, wherein said passivation layer comprises:

a 1^{st} passivation tier, having a respective 1^{st} and 2^{nd} surface, said 1^{st} passivation tier having a plurality of depressions; and

a 2^{nd} passivation tier, having a respective 1^{st} and 2^{nd} surface, wherein said 2^{nd} passivation tier 1^{st} surface is in contact with said 1^{st} passivation tier 2^{nd} surface, said 2^{nd} passivation tier forming a plurality of mesa tops.

24. A radiation imager in accordance with claim **23**, wherein said 1^{st} passivation tier and said 2^{nd} passivation tier respectively comprise different passivation materials.

25. A radiation imager in accordance with claim **24**, wherein said 2^{nd} passivation tier material comprises a polyimide layer.

26. A radiation imager in accordance with claim **24**, wherein said 2^{nd} passivation tier material comprises a SiO_2 layer.

27. A radiation imager in accordance with claim **24**, wherein said said 1^{st} passivation tier comprises a SiN layer.

28. A radiation imager in accordance with claim **23**, wherein said 2^{nd} passivation tier thickness is in the range between about 0.1 μm and about 2 μm.

29. A radiation imager in accordance with claim **23**, wherein said said 1^{st} passivation tier thickness is in the range between about 0.1 μm and about 5 μm.

30. A high integrity radiation imager comprising:

a passivation layer having an adhesion topography, said adhesion topography comprising an upper surface of said passivation layer; and

a scintillation layer disposed over said adhesion topography,

wherein said adhesion topography comprises a plurality of mesa tops and depressions.

31. A high integrity radiation imager in accordance with claim **30**, wherein said adhesion topography comprises mesa tops disposed between said depressions.

32. A high integrity radiation imager in accordance with claim **30**, wherein the distance between adjacent ones of said mesa tops is in the range between about 2 μm and about 500 μm.

33. A high integrity radiation imager in accordance with claim **30**, wherein shape of said mesa tops are square, circular, rectangular or irregular.

34. A high integrity radiation imager in accordance with claim **30**, wherein the distance between adjacent ones of said depressions is in the range between about 5 μm and about 500 μm.

35. A high integrity radiation imager in accordance with claim **30**, wherein sidewalls of said depressions are flush with said mesa tops.

36. A high integrity radiation imager in accordance with claim **30**, wherein sidewalls of said depressions extend beneath said mesa tops creating an undercut portion.

37. A high integrity radiation imager in accordance with claim **30**, wherein said undercut has a length in the range between about 0 μm and about 1 μm.

38. A high integrity radiation imager in accordance with claim **30**, wherein said scintillation layer comprises Cesium Iodide.

39. A high integrity radiation imager in accordance with claim **30**, wherein said scintillation layer is disposed within said depression and over said mesa tops.

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